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Scope, study and experimentation of biopac kit and its implications on a brain controlled robotic arm

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ABSTRACT

In today's world, many problems are faced by the people who are paralyzed. The prosthetic surgery costs millions of bucks but still the movement of the limbs is not obtained as desired. So it is worthy to create a robotic arm which will work directly with the help of brain pulses and hence directly through thoughts. BCI allows users to communicate with others by using only brain activity without using peripheral nerves. On BCI research the Electroencephalogram (EEG) is used for measuring the electrical activities along the scalp. EEG is hence used to measure the voltage fluctuations resulting from ionic current flows within the neurons of the brain. A Biopac kit is used to collect the pulses from the brain. Here, experiments are performed on 6 subjects and nearly 200 samples have been collected. These data have been analyzed and converted into numerical form in terms of voltage. This range of voltages is to be provided to the microcontroller which actuates the robotic arm. This robotic arm is designed to grip the objects when it receives the signal from the microcontroller. So an attempt is made to make a low cost automatic brain controlled artificial arm.

Keywords: Brain Computer Interface (BCI), Neuron, Electroencephalography (EEG), Brain Control.

1. INTRODUCTION

Who wouldn't love to control a robotic device with their mind? Interfaces between the brain and computers have long been a staple of science fiction where they are used in an incredible variety of applications from controlling powered exoskeletons, robots, and artificial limbs to creating art envisioned by the user to allowing for machine-assisted telepathy. This space-age fantasy is not quite real yet, however simple BCIs do currently exist and research and public interest in them only continues to grow. BCI techniques are broadly divided into invasive and non-invasive techniques. Non-invasive BCI is a fast growing field in which a lot of progress is being done in research. These days, noninvasive BCI techniques are continuously catching people's attention over invasive BCI techniques. This is because of the fact that over decades it has been believed that invasive techniques with electrodes stuck in the brain alone could restore people with more complex disabilities. The examples of this are providing control over a robotic arm for limb actuation, moving the wheel chair for paralyzed people in the desired directions.

I). Electroencephalography (EEG)

EEG is the first non-invasive neuro imaging technique discovered useful for observing and measuring the electrical activity of the brain. Because of its easy use, lower cost and high temporal resolution this method is the most preferably used one in BCIs nowadays. As stated before, the discoverer of the existence of human EEG signals was Hens Berger (1873-1941). He started his study of human EEGs in 1920. Berger began his work on a string galvanometer in 1910, and then went to a smaller Edelmann model, and after 1924, to a larger Edelmann model. In 1926, Berger began utilizing the more powerful Siemens double coil galvanometer which could attain a sensitivity of 130 V/cm. The initial report of human EEG recordings of the duration of one to three minutes was on photographic paper and was recorded in 1929. In the recording that he made, he used only a one-channel bipolar method with front occipital leads. The popularity of recording of the EEG increased in 1924. The first report of 1929 by Berger included the alpha rhythm as the prime component of the EEG signal. During the phase of 1930s, the first EEG recording of sleep spindles was performed by Berger.

II). Literature Review

Yuanqing Li et al present how to control a cursor in 2D using EEG based brain computer interface. The experiment was performed for the movements of the cursor on the computer screen to be controlled by the scalp potentials. The EEG signal is taken from the user head to the 2D cursor control. The horizontal motion is taken from the beta rhythm and vertical motion is based on P300 potential respectively. The cursor can me moved horizontally to the right just by imagining the right hand motion and the same way the left hand motion imagination is used to move the cursor left. The cursor can be moved vertically upwards by focusing on one of the three UP buttons on the monitor and similarly downwards by focusing on the either of the three DOWN buttons.

Jinyi Long, Yuanqing Li et al emphasize on the selection of BCI 2D cursor using an extremely hybrid feature. As found in most of the applications, 2D cursor control is used to control processes in sequence, which involve cursor control and target selection. The paper emphasizes on the target selection of the cursor using a hybrid feature from P300 potential and motor imagery. It has a significant advantage of better performance compared to other systems.

Francisco Velasco-Álvarez et al focus on the use of the proposed interface in order to control a real wheelchair without needing a screen to obtain visual stimuli or feedback.

2. DEFINITION AND ESSENTIAL FEATURES OF A BRAIN–COMPUTER INTERFACE (BCI)

Since the EEG was first described by Hans Berger in 1929, people have speculated that it might be used for communication and control, that it might allow the brain to act on the environment without the normal intermediaries of peripheral nerves and muscles. In the 1970's, several scientists developed simple communication systems that were driven by electrical activity recorded from the head. Early in that decade, the Advanced Research Projects Agency (ARPA, which also sponsored the initial development of the internet) of the U.S. Department of Defense became interested in technologies that provided a more immersed and intimate interaction between humans and computers and included so-called "bionic" applications. A program proposed and directed by Dr. George Lawrence focused initially on auto regulation and cognitive biofeedback. It sought to develop biofeedback techniques that would improve human performance, especially the performance of military personnel engaged in tasks that had high mental loads. The research produced some valuable insights on biofeedback, but made minimal progress toward its stated goals. A new dimension was given under the more general label of "biocybernetics" and was then defined and became the main source of support for bionics research in the ensuing years. One of the principles of the biocybernetics program was to measure the possibility that biological signals, analyzed in real-time by computer, and could assist in the control of vehicles, weaponry, or other systems. The most successful project in this area was that headed by Dr. Jacques Vidal, Director of the Brain–Computer Interface Laboratory

at UCLA. Using computer- generated visual stimulation and sophisticated signal processing, the research showed that single-trial (i.e., not averaged) visual evoked potentials (VEP's) could provide a communication channel by which a human could control the movement of a cursor through a two-dimensional maze [1].

The early work also served to bring out the fundamental distinction between EEG-based communication that depends on muscle control (e.g., visual evoked potentials that depend on where the eyes are directed), and EEG-based control that does not depend on muscle control. These distinctions shaped the definition of the term BCI put forward in this session: "The brain–computer interface is a form of communication system that is not dependent on the brain's normal output paths of peripheral nerves and muscles." This definition also mirrors the principal reason for recent interest in BCI development—the possibilities it offers for providing new communication technology to those who are paralyzed or have other severe movement deficits.

I). TYPES OF BCI

Invasive – It is the brain signal reading process which is applied to the inside of grey matter of brain.

Partially Invasive – It is another brain signal reading process which is applied to the inside the skull but outside the grey matter. Electrocorticography (ECoG) is the example of partially invasive BCI.

Non Invasive – It is the most useful neuron signal imaging method which is applied to the outside of the skull, more precisely on the scalp. Electroencephalography (EEG) is the most studied in the last decade and in the recent time most of the researches are based on EEG. Apart from the EEG, some non-invasive neuron signal imaging or reading techniques prevail, such as: Magneto-encephalography (MEG), Magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI).

II). Invasive BCI Methods:-

The opportunities and difficulties associated with using invasive methods for obtaining BCI control signals can be reviewed. This is a subject of discussion whether the observation that the invasive methods are appropriate only if they are safe and if they provide significant functional improvements as compared to noninvasive methods. The discussion can be focused on five important questions. [3]

First, what are the possible locations of implanted electrodes and what signals will they record? The motor cortex is an obvious choice for recording and should be considered in most cases because it relates directly to motor tasks, its relative accessibility as compared to motor areas in the brain, and the relative ease to record from its large pyramidal cells. Other sites that might be considered include the supplementary motor cortex, subcortical motor areas, and the thalamus. Functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and other functional imaging techniques could help identify appropriate areas for implantation. Estimates range from the expectation that one or two cortical neurons can provide useful information from an otherwise locked-in brain to the belief that 50 to100 neurons will be needed to provide an information transfer rate that justifies an invasive procedure.

Second, what are the options for obtaining stable recording capability over months and years? In small-brained animals such as rats and guinea pigs, stable single-unit recording has been maintained for long periods. In nonhuman primates stable recording has been maintained over months, and in selected instances over years. Recent results indicate that the cone electrode may provide stable recording in primates, including humans, for periods of years. Other promising microelectrodes include microwires and micromachined microelectrode arrays. Further electrode development, combining the multisite capability of micromachined electrodes with the long-term stability of the cone electrode, is essential.

Third, which user groups might be best suited, by disability and/or need, for implanted electrodes? Patients who are locked in (e.g., by ALS) might benefit from invasive BCI technology if it is both safe and effective. Selected individuals with stroke, spinal cord injury, limb prostheses and other conditions might also benefit. Apart from the issues of safety and efficacy, the stigma sometimes associated with brain implants must be addressed and overcome. Individual preferences will play a significant role in decisions about implantable systems. To be justifiable, an implanted system must offer the individual a substantial functional advantage over conventional augmentative technologies and over noninvasive BCI methods.

Fourth, to what extent will the control provided by recorded neurons be able to be independent of the presence of normal feedback from other CNS areas? Implanted microelectrodes have been likened to a wiretap where the microelectrodes listen in to a normal conversation between cells. For users who are paralyzed or have other severe neuromuscular disabilities, it might be more appropriate to say that the implanted array of microelectrodes is a wiretap into a conversation in which one party has hung up. An effective BCI must provide feedback to the user and thereby substitute for the missing part of the conversation. The ability of the nervous system to change so as to respond in an effective manner to the new feedback provided by a BCI will have a major role in determining how well the communication system works.

Fifth, what are the ethical issues that must be considered in implanting recording electrodes in human volunteers? Patients must be informed of the risks and potential benefits of any intervention, especially an invasive procedure with uncertain benefit to the individual and possibly serious risks. Volunteers with severe disabilities may tend to greatly overestimate the potential benefits, so that risks and uncertainties must be clearly and forcefully explained. On the other hand, many people may want to volunteer for research that provides no direct benefit to themselves beyond the knowledge that they are participating in a research project that might help others with similar conditions in the future. They should not be denied this opportunity. An ethicist should be involved in the earliest phases of any human research developing or testing invasive BCI methods.

3. SYSTEM DESIGN

The system is categorized into three blocks as shown in Fig.1, EEG signal acquisition, signal transmission and signal processing, each targeting at the acquisition of the EEG signal from user scalp. The scalp potentials are then amplified, digitized and transmitted to a controller that further processes to map them to a robotic arm control.

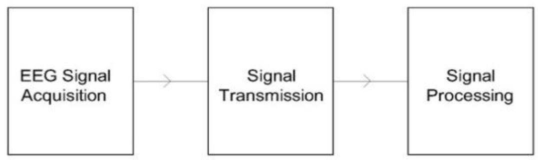

Figure 1 System Design

I). EEG Signal Acquisition:-

This stage basically targets at the precise extraction of the EEG signal from the user scalp. It is made up of different blocks such as amplifiers and filters such as notch filter. The purpose of the instrumentation amplifier is to extract the EEG signal. The extracted EEG signal is passed through the operational amplifier block for proper amplification, as shown in Fig.2. It is then passed through the different filters such as high pass, low pass and notch filters. The job of the high pass filter is to remove the noise in the signal. The job of the low pass filter is to extract the signal frequencies of interest. Because of the fact that the DC power supplies are used, one common problem that will be existing is the 50 Hz power line signal. This 50 Hz power line signal will distort the EEG scalp potentials. The combination of a notch filter will consequently filter out this power line signal which is undesirable.

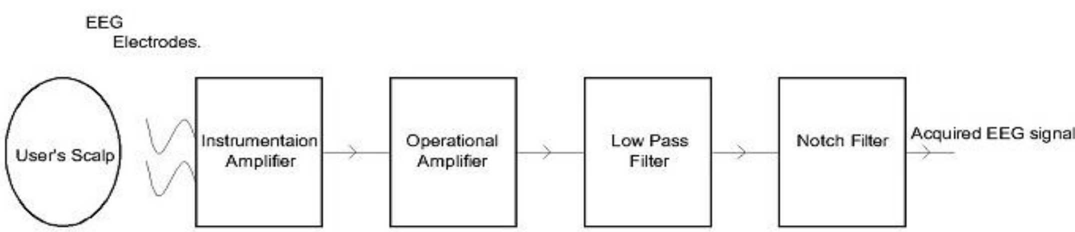

Figure 2 Flow Diagram

II). BCI Translation Algorithms:-

A translation algorithm is a series of calculations that converts the BCI input features obtained by the signal processing stage into real device control commands. To put it in other words, a translation algorithm takes abstract feature vectors that show specific features of the present state of the user's EEG or single-unit activity i.e., aspects that encode the message that the user desires to convey and converts those vectors into application-specific device commands. Different BCI's use different types of translation algorithms. Each of these algorithms can be classified in terms of three essential features: transfer function, adaptive capacity, and output. The transfer function can be linear e.g., linear discriminant analysis, linear equations or nonlinear e.g., neural networks. The algorithm can be adaptive or non-adaptive. Adaptive algorithms can use simple handcrafted rules or more sophisticated machine-learning algorithms. The output of the algorithm may be discrete e.g., letter selection or continuous e.g., cursor movement. The diversity in translation algorithms among research groups is due to diversity in their desired real-world applications. However, in all cases the goal is to improve the performance and practicability for the intended application. Present consideration of alternative translation algorithms emphasizes primarily on those applicable to scalp-recorded EEG activity because presently, it is the only widely available BCI option for human users. Because of the evolution of new invasive technologies (e.g., the cone electrode or

intracortical or subdural arrays), extant algorithms require additional evaluation and new algorithms will arise. EEG activity reflects the activity of an extremely large number of cortical neurons. If the input features obtained from this activity are to provide efficient communication, they must have two or more discernible states that show the user's intentions and are accommodated to the domain and constraints of the application. [3]

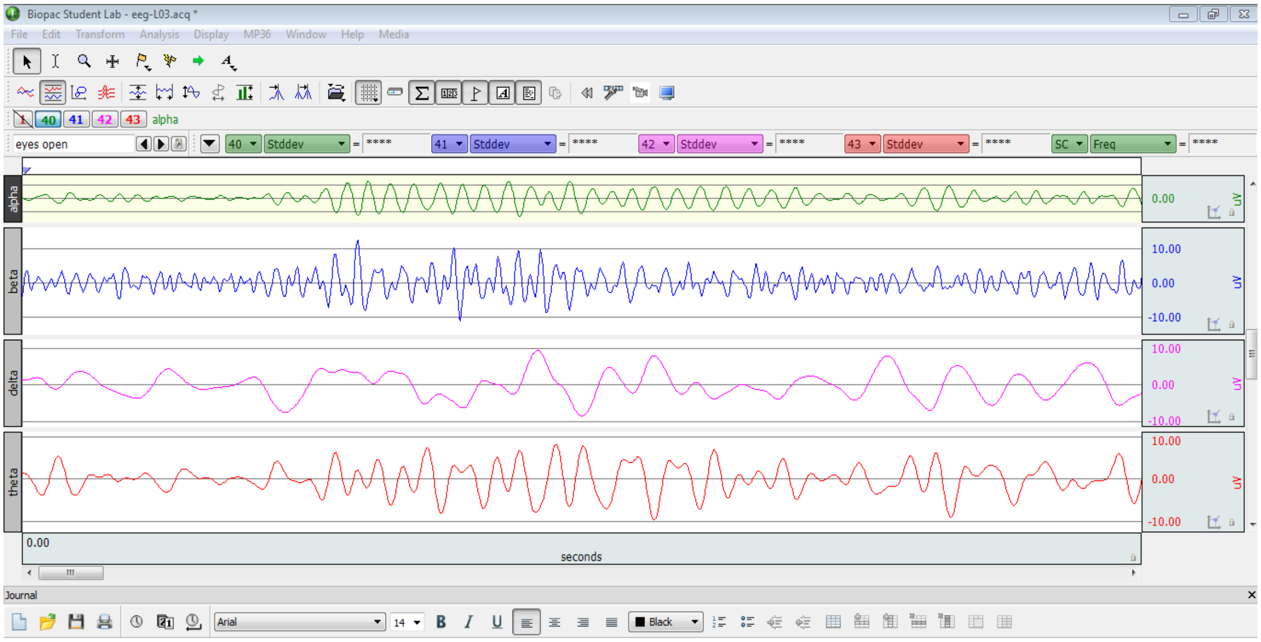

Figure 3 Sample EEG Acquisitions

A1 | Time

	A	B	C	D	E	F
1	Time	CH 1, EEG	CH40, alpł	CH41, bet	CH42, delt	CH43, theta
2	sec	uV	uV	uV	uV	uV
3	0	0.189209	0.17486	-4.00922	1.350506	1.281477
4	0.005	-3.8208	-0.12922	-2.26607	1.301724	1.345436
5	0.01	1.837158	-0.57832	0.555531	1.283317	1.363248
6	0.015	6.311035	-1.07197	2.563671	1.294039	1.312693
7	0.02	-0.50049	-1.47362	3.340928	1.332084	1.183878
8	0.025	-7.75757	-1.66287	2.976237	1.395447	0.978745
9	0.03	-3.72925	-1.61356	1.23355	1.480532	0.700502
10	0.035	0.500488	-1.38308	-1.15454	1.581316	0.349662
11	0.04	-6.28052	-1.0306	-2.27311	1.690414	-0.06828
12	0.045	-13.9709	-0.59486	-1.43621	1.79996	-0.53957
13	0.05	-10.5225	-0.13742	-0.19318	1.900878	-1.04959
14	0.055	-5.01709	0.266503	0.151948	1.982546	-1.58569
15	0.06	-9.10034	0.595206	0.275313	2.034409	-2.12888
16	0.065	-14.5142	0.88754	0.99768	2.047635	-2.64921
17	0.07	-8.89282	1.177163	1.597192	2.015175	-3.11263
18	0.075	-2.20337	1.468545	1.297492	1.931831	-3.48602
19	0.08	-5.98755	1.772747	0.708253	1.795632	-3.73394
20	0.085	-11.4075	2.100064	0.40631	1.608713	-3.81978
21	0.09	-6.96411	2.403466	-0.26392	1.37622	-3.71744
22	0.095	-0.43945	2.583527	-1.62064	1.105109	-3.41861
23	0.1	-3.22876	2.564249	-2.48316	0.804474	-2.92788
24	0.105	-7.15942	2.325357	-1.93982	0.485874	-2.25845
25	0.11	-1.13525	1.867498	-0.81049	0.162264	-1.43582
26	0.115	5.584717	1.206928	-0.12129	-0.15297	-0.49808

eeg-L03

Figure 4 Voltage Values for EEG Acquisition

III). Working of three electrode EEG kit (Biopac Kit):-

The Biopac Kit consists of three channels for the extraction of various pulses. These channels include MP35, MP36 and MP45 channels. This device gives the output in the form of various pulses such as alpha, beta, theta and delta. All these waves have a specific voltage level for each activity. The Electroencephalography works at the frequency range of 5 Hz to 35 Hz. The process involves the use of three electrodes made up of silver chloride which are stuck to the scalp of the subject at predefined locations.

The process of extraction of the pulses incudes Rapid Eye Movement (REM). The subject is asked to make a rapid eye movement and then the variation in the pulses is observed. A sample EEG acquisition is shown in Figure 3.

IV). Signal Analysis:-

The target of signal analysis in a BCI system is to optimize the signal-to-noise ratio (SNR) of the EEG. In order to achieve this, it is necessary to consider the major sources of noise. Noise has both non-neural sources e.g., eye movements, EMG, 50-Hz line noise and neural sources e.g., EEG features other than the ones that are used for communication. Noise detection and other discrimination issues are greatest when the characteristics of the noise are alike in frequency, time or amplitude to those of the required signal. For instance, eye movements are of greater importance than EMG when a slow cortical potential is the BCI input feature since eye movements and slow potentials have the frequency ranges that overlap.

In this case, the pulses obtained are converted into their equivalent numerical form wherein each number represents the corresponding voltage level of each activity. The values may be obtained for time intervals as low as 5 milliseconds. Hence, several lakhs of values may be obtained for each experiment performed. The voltage values for the graph shown previously can be given as shown in Figure 4.

4. MECHANICAL DESIGN

This phase includes the design of the entire assembly of the robotic arm at once and then checks the design for safety when the assembly is subjected to loads.

I). Design of Reliable Mechanical Joints:-

The function of a joint is to allow relative motion between two links or arms of a robot. It provides controlled relative motion between two links that is, input and output links. Usually, one joint provides one degree of freedom. There are different types of joints such as the linear joints, rotational joints, revolving joints, orthogonal joints and twisting joints. Of the given joints the rotational joints are easy to manufacture and is best suitable for our demand. Thus hinged joints are used. The cost of hinged joints is very less and can best satisfy our requirement. However based on the strength and weight to be lifted various types and quality of hinged joints is used.

II). Manipulator Design:-

A manipulator is usually mounted on a track or suspended from a track that is capable of reaching to indeterminate distances and locations. It is capable of moving materials, objects and tools without direct human contact. It has two sections which are the body or arm and the wrist assembly.

III) Design of body:-

The body is used to position the object in the robot's work envelop. Hence properly using the concept of value engineering proper design can help reduce the weight of the body and also the quantity of materials used. In order to optimize both material cost and the manufacturing cost, the arm is made of different components and is then assembled together, thereby saving the material and reducing the cost.

IV). Design of wrist assembly:-

It is used for the positioning of the object in the work envelop. To the wrist assembly, the end effector is attached. There are three degrees of freedom pitch, roll and yaw of the wrist assembly. But for simple pick and place application considering the complexity of manufacturing of the wrist assembly, the end effector can be directly attached to the arm using hinged joints. In most cases, pneumatic cylinder is used for controlling the end effector. Doing so can significantly reduce the cost of the robot.

V). Design of End Effector:-

For positioning the object, the arm is very important. The end effector grips the object. The end effector is the hand of the robot. The different types of end effectors are grippers, sprayers, grinders, vacuum and welders. In this case, either a gripper or a vacuum can be used. A gripper used for lifting and placing objects is widely used because of its ease to design and manufacture. Pneumatic power can be used to make the system cheaper and a better option.

VI). Rotation of the Robot:-

For the robot to reach different locations and perform the tasks it has to rotate around its own axis. Hence according to the requirement, either a stepper motor or a simple pneumatic cylinder can be used. A stepper motor needs electronic circuits for control and an additional bearing support for 360 degree rotation. However if a 90 degree span of rotation is sufficient then a pneumatic cylinder can be used. In this case, only one bearing to support the rotation is required thus considerably reducing the cost of the robot. The parts of the assembly of the robotic arm are shown in Figure 5.

The material which has higher strength to weight ratio has to be preferred while designing all the parts. So an obvious choice of the material would be aluminum. But the problem of using aluminum is that the load that it would experience would be vertically downwards, so there is a possibility of bending for the aluminum sheets of lesser thickness. So an alternate material that can be selected is acrylic which can take up more amount of load and also its weight is comparatively lesser. The 3D view of the complete assembly is shown in Figure 6:-

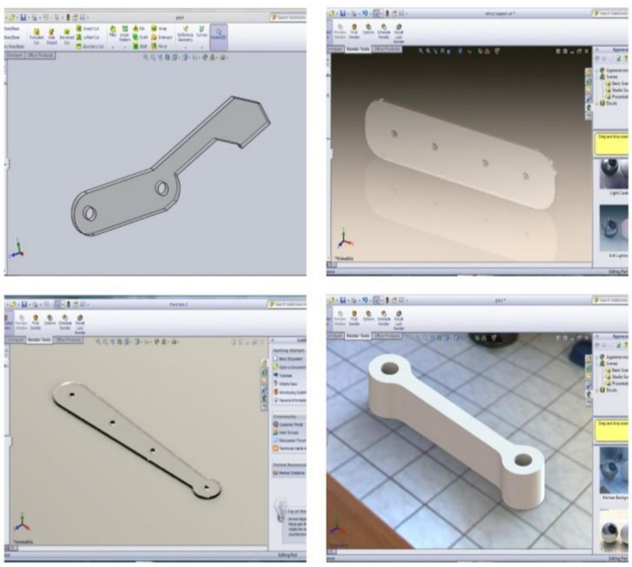

Figure 5 Parts of the Assembly of the Robotic Arm

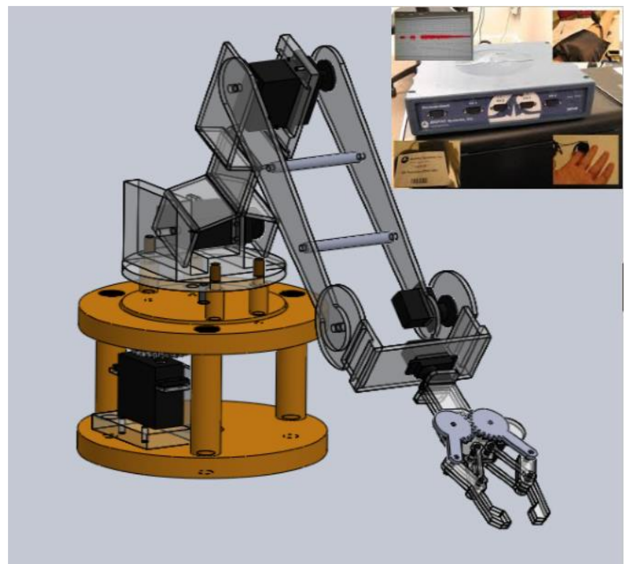

Figure 6 Simulated model of the System

5. CONCLUSION & FUTURE SCOPE

Numbers of experiments are performed and data has been collected. Here it is evident that the system cost is low but it has numerous disadvantages. Because of lesser number of electrodes, the results that are obtained are not so accurate and hence, the movement of the robotic arm that is to be obtained will not be as per the expectations. The system operation is not real time. Also, the analysis of lakhs of values for experimentation time of minutes becomes a very cumbersome process. The delay in the movement is around 20 seconds. The designed robotic arm is cheaper and can carry one Kg load easily. Consequently, the demand of the situation is the use of devices with more number of electrodes so that better results can be obtained. One such device that can be used is EPOC Emotiv Headset which consists of 14 electrodes at definite locations which eliminates the possibility of manual positioning of the electrodes on the scalp.

REFERENCE

1. Yuanqing Li "An EEG-based BCI System for 2D Cursor Control", IEEE International Joint Conference on Neural Networks, 2008. IJCNN 2008. (IEEE World Congress on Computational Intelligence).
2. Jinyi Long "Target Selection with Hybrid Feature for BCI-Based 2-D Cursor Control", IEEE Transactions on Biomedical Engineering, Jan 2012
3. Grübler (2012). Psychosocial and ethical aspects in non-invasive EEG-based BCI research – A survey among BCI users and BCI professionals. Neuroethics
4. Francisco Velasco-Álvarez, Neurocomputing, Volume 121, 9 December, 2013, Pages 89-98.
5. W. D. Penny, "EEG-based communication: A pattern recognition approach," IEEE Trans. Rehab. Eng., vol. 8, pp. 214–215, June 2000.
6. S. P. Levine., "A direct brain interface based on event-related potentials," IEEE Trans. Rehab. Eng., vol. 8, pp. 180–185, June 2000.